Faculty of Electrical and Electronic Engineering Technology

TREEING AND TRACKING OBSERVATION ON THE SURFACE OF TRANSMISSION LINE INSULATOR FOR SOLVING LINE-TO-GROUND FAULT IN DC HIGH VOLTAGE APPLICATION

YEE LU HUAN

Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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TREEING AND TRACKING OBSERVATION ON THE SURFACE OF TRANSMISSION LINE INSULATOR FOR SOLVING LINE-TO- GROUND FAULT IN DC HIGH VOLTAGE APPLICATION

YEE LU HUAN

A project report submitted
in partial fulfillment of the requirements for the degree of
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours

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Date :

DEDICATION

To special feeling gratitude to my loving parents, Yee Yep Meng and Loo Swee Lim, whose words of encouragement and push for tenacity ring in my ears.
And my most respectful supervisor Ts Dr Zikri Abadi Bin Baharudin for helping me a lot in develop my technology skills.
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ABSTRACT

Throughout the proposal of this final year project is regarding on the photographic observation for electrical treeing and tracking observation on the surface of transmission line insulator for solving line-to-ground fault in DC high voltage application via high-speed camera. Since formation of electrical treeing and contamination of tracking may lead to breakdown in high voltage system. The observation of the existence of electrical treeing may provide insight into how to diminish the risk of a breakdown occurring in a high voltage system of the line to ground fault as a precaution to prevent the breakdown triggered phenomenon in a high voltage system. The main purpose of this final year project is to investigate the propagation progress of electrical treeing and tracking on the surface of the ceramic insulator by using the combination of electric field measurement and high-speed photographic camera. This project was conducted in Universiti Institut Voltan Dan Arus Tinggi (IVAT) lab from Universiti Teknologi Malaysia, Skudai, Malaysia. A ceramic insulator KN120 used to see the formation of electric treeing and tracking by applying high voltage DC ranging from 30 to 50 kV. For the purpose of photographic and electric field observation and measurement, this project used Choronos 1.4 High speed camera and broadband electric field measurement. The resolution of high-speed camera was set to 1000 frame per second (fps) within the duration of 2 seconds. Electrical breakdown voltage was recorded by using high defination of transient recorder (Lecroy HDO4024) with the resolution ranging from 10 to 20 MS/s for 2 seconds duration. The results of this project comprises three important findings: a) When the DC voltage exceed up to 20 kV, treeing and tracking start forming at the bottom of the insulator that being terminated by HV terminal (+); b) Treeing and tracking appeared as train pulses ranging from 9 to 10 MHz between the two peaks (as summarized in Table 4.1); c) Peak voltage due to treeing and tracking variation associated in DC input and not consistence or not uniform range (as summarized in Table 4.2).

ABSTRAK

Cadangan projek tahun akhir ini adalah mengenai pemerhatian fotografi dalam bentuk pokok elektrik dan pemerhatian pengesanan pada permukaan penebat talian penghantaran untuk menjejak kesalahan talian ke tanah menggunakan aplikasi voltan tinggi DC melalui kamera berkelajuan tinggi. Disebabkan pembentukan pepohonan elektrik dan pencemaran penjejakan boleh menyebabkan kerosakan dalam sistem voltan tinggi, pemerhatian kewujudan pepohonan elektrik boleh memberikan gambaran tentang cara mengurangkan risiko kerosakan yang berlaku dalam sistem voltan tinggi sesar ke tanah sebagai langkah berjaga-jaga untuk mengelakkan fenomena kerosakan dalam sistem voltan tinggi. Tujuan utama penyelidikan ini adalah untuk memerhatikan menggunakan kamera berkelajuan tinggi bagi memerhatikan pembentukan pokok elektrik berkaitan dengan peningkatan bekalan voltan boleh menjadi pembentukan semak, cawangan, cabang belukar dan sebagainya. Projek ini akan dijalankan di Universiti Teknology Skudai, Malaysia (UTM) dan menjalankan hasilnya dengan menggunakan radas daripada Institut Voltan Dan Arus Tinggi (IVAT) lab UTM. Proses akan dijalankan untuk bekalan voltan lebih daripada 33kV disebabkan atas bantuan daripada Universiti Teknology Skudai, Malaysia (UTM) dan radas-radas dari lab Institut Voltan Dan Arus Tinggi (IVAT). Projek ini perlu menggunakan Choronos 1.4 High speed camera untuk rekod pembentukan pokok elektrik. Penebat seramik KN120 dari High Voltage UTeM juga akan digunakan untuk permerhatian cara pembentukan pokok elektrik. Pemerhatian jarak akan dijalankan dalam halangan sekitar 2 hingga 5 meter di dalam sangkar keselamatan. Ujian ini akan menganalisis masa yang terpaksa berlaku kerana pecahnya berlaku disebabkan oleh peningkatan voltan tinggi yang terjejas oleh peningkatan gerakan rel berkelajuan tinggi.

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First and foremost, I would like to express my gratitude to my supervisor, Ts Dr Zikri Abadi Bin Baharudin for his precious guidance, words of wisdom throughout this project.

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Emax	-	Electric field
r	-	weighted mean average of tip radius of curvature of the needle electrode
α	-	Townsend ionization coefficient
N	-	Negative ions in the avalanche
U	-	Applied Voltage magnitude
x	-	Distance from avalanche starting point
d	-	Insulation thickness from the needle tip to the center
Lm	-	Maximum or final tree branch length
τe	-	Time constant
L(t)	-	Tree length growth
Tm	-	Total bond energy of the molecules
t-t1	-	Period followed the inception at t1
Tc	-	Breaking produce free carbon

LIST OF ABBREVIATIONS

UTeM	-	Universiti Teknikal Melaka Malaysia
FTK	-	Fakulti Teknologi Kejuruteraan
PD	-	Partial Discharge
UTM	-	Universiti Teknology Skudai Malaysia
IVAT	-	Institut Voltan Dan Arus Tinggi
	-	

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CHAPTER 1

INTRODUCTION

1.1 Background

An insulator's solid non-conducting constituent is known to exhibit electrical treeing, a physical dielectric phenomena. On the either, it is also well recognised that electrical treeing, which occurs in solid insulation before failure due to partial discharges in high voltage engineering, is a phenomena. Failure of high voltage insulation systems is frequently caused by electrical treeing. The insulator's dielectric stress causes electrical treeing. Figure 1.1 depicts the development of electrical treeing, which is one of the pathways to failure in polymeric cable insulation because it causes material breakdown in areas of higher electric stress, such voids, protrusions, and water trees. Due to a high electrical field during a breakdown, there is electrical treeing.The encouragement or repulsion of one electric charge by another at any location is quantified as an electric field. the appositive charge's proximity to the charge vector and the amount of force applied therein in relation to that charge. As a result, the strength of the electric field is derived from electric charge. According to Farr et al. (2001), it is hypothesised that tree development occurs along an active, conductive tree channel with a local growth probability that is correlated with electric field strength. In a high voltage system with an insulator, electrical tree growth is a sign of impending electrical breakdown. As a result, the electrical tree growth was split into three stages: beginning stage, intermediate stage, and pre-breakdown stage. Furthermore, electrical treeing growth is classified into two different types: Vented Type and Bow-tie Type trees. Vented Type trees are more frequently found than a Bow-tie Type trees and are also more dangerous compare with it. Vented trees are classified into three types which is Branch Type, Bush Type, andBush-branch Type (Malik et al 2005).

Figure 1.1 Branch Type, Bush Type, andBush-branch Type (Malik et al 2005)

According to (Bao et al. 2011), the Electrical Treeing tree structure characteristics shown in Figure 1.2 include distribution and transformation character. Furthermore, voltage injection, frequency, and pin-plane spacing will all have an effect on tree structure characteristics. The development of tree structures is frequently influenced by local electric field and frequency. Electrical tree propagation characteristics are sensitive and affective with too many elements in polymer. An injection of stress voltage and frequency can impact the pace of development and the structure of treeing creation because frequency accelerates the growth process whenever the number of gas discharges increases but has no effect on the type of the discharge. In other words, the applied voltage determines the amplitude of the local electric field at the tip of the discharge columns. The applied voltage has a direct influence on the geometry of electrical trees.

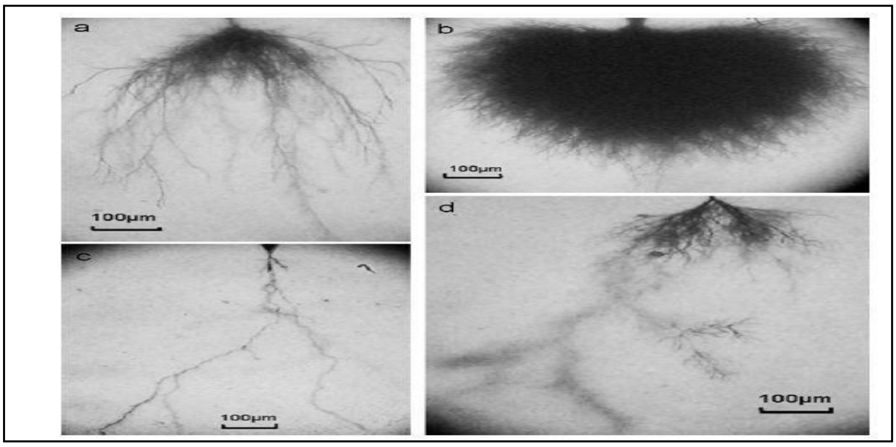

Figure 1.2 Electrical Treeing with different structure adapted from (Bao et al. 2011)

Suspension Disc Insulator Ceramic Insulator, as seen in Figure 1.3, are generally implemented in power systems to provide electrical insulation and mechanically support for high-voltage transmission lines. These insulators are subjected to a variety of stresses, including mechanical, electrical and environmental. These stresses act in unison. The exact nature and magnitude of these stresses vary significantly and depends on insulator design, application and its location. Due to various reasons the insulator disc can lose its electrical insulation properties without any noticeable mechanical failure. Such a condition while difficult to recognize, can enhance the stress on remaining healthy insulator discs in the string further may lead to a flashover. To understand the stress enhancement due to faulty discs in a string, attempt has been made to simulate the potential and electric field profiles for various disc insulators presently used in the country. The results of potential and electric filed stress obtained for normal and strings with faulty insulator discs are presented(Kumar and Satish et al 2012.

Figure 1.3Suspension Disc Insulator Ceramic Insulator adapted from (https://www.powertelcom.com/electrical-insulator/suspension-insulator/https://www.tciinsulator.com/home/productdetail/Porcelain-Disc-Insulator_74.html)

Minimal of level electrical stress and a certain time that can contribute to the onset of electrical treeing are characterized as the initial infection following voltage application. During the experimental period, charge carriers travel back and forth among the electrodes and the dielectric stress. This repetitive courier charge is the main cause of the onset of electrical tress. After going through the electrical treeing process, measurable partial discharge will trigger tree growth and finally dielectric collapse. Trees can sometimes be initiated and propagated by contaminated particles or cavities (Malik et al. 2005). The partial discharge that occurs in dry dielectric isolates this contaminating particle from the surface of the insulation and void.

Formation of vented trees are apparent, and their visual appearance varies widely based to the situation whereby a initiation and growth are monitored using a high-speed camera. Formation Vented tree development begins at an electrode interface on the inner or outer surface of the insulation layer, with a contact between the insulation and its semiconductive layer. The growth of bow-tie trees is symmetrical with the nucleus and extends in both necessarily involve to the electric field. Furthermore, these bow-tie tree growths are caused by a lack of unrestricted air supply to sustain partial discharge and progress the tiny filamentary way. The development of bow-tie trees could be seen to be sporadic. These apparent discharges alternate with extended periods of extinction. (Malik et al. 2005). Extinction is the result of increasing void stress caused by ionisation in the void. Whereas the transmission of electrical treeing branches occurs related to the existence of electrical discharge, light phenomena are also a factor that supports them. (Laurent and Mayoux 1980).

Ceramic outdoor insulators also play an important role in electrical insulation and mechanical support because of good chemical and thermal stability, which have been widely used in power systems. However, the brittleness and surface discharge of ceramic material greatly limit the application of ceramic insulators. From the perspective of sintering technology, flash sintering technology is used to improve the performance of ceramic insulators. In this paper, the simulation model of producing the ceramic insulator by the flash sintering technology was set up. Material Studio was used to study the influence of electric field intensity and temperature on the alumina unit cell. COMSOL was used to study the influence of electric field intensity and current density on sintering speed, density and grain size. Obtained results showed that under high temperature and high voltage, the volume of the unit cell becomes smaller and the atoms are arranged more closely. The increase of current density can result in higher ceramic density and larger grain size. With the electric field intensity increasing, incubation time shows a decreasing tendency and energy consumption is reduced. Ceramic insulators with a higher uniform structure and a smaller grain size can show better dielectric performance and higher flashover voltage.High-speed cameras will be used to help and support researchers in the fields of high- speed aerodynamics, ballistics, and other high-speed phenomena. Taking pictures at rapid speeds do not need the use of film that travels intermittently. Due to the split and when accelerating to the right speed, the magazine cannot provide film in extremely high speed situations

Electrical tracking is defined as partial breakdown in any gas mixture and the interaction of vacuum with solid and liquid dielectrics, which can result in the formation of a conducting path due to various factors such as humidity, pollution, local voltage increment, and ice load, which might affect the dielectric surface. As a result, estimating the insulator's lifespan is challenging. As a result, the presence of surface discharge on an organic solid insulator is the main source of failure in high voltage systems (İbrahim Gü neş 2015). In other words, the interaction of a high tangential component of an electric field along a diagonal with a solid, liquid, or gaseous medium causes surface partial breakdown.

Organic insulating materials have gained wide acceptance for use as electrical insulation in high voltage electrical appliances. As a result, surface tracking breakdown of an organic insulating material is a serious concern that can have a significant impact on the safety and reliability of an electrical appliance when it exceeds high local temperatures caused by discharge, which causes carbonization on the surface of organic insulating materials until breakdown(Yoshimura et al. 1981). Surface discharge occurs when the field component located at the surface exceeds the medium of electric strength caused by a conducting layer over the surface of the dielectric due to an obstruction of the creepage current channel. Others, such as creepage currents through the conducting film, cause mechanism interruptions that are influenced by discharge operations. The tracking phenomena changes with the strength of the field, the strength of the current, and the conditions of discharges on the surface caused by wet surfaces, which are connected to the degree of contamination. Contaminants that can cause breakdown include salt content, dust particles, and humidity that react with air chemical agents. (Yoshimura and Kumagai et al. 1997).